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Carl Hering
Feb 19 - 1911

Gould Storage Battery Co.

STORAGE BATTERIES ON ALTERNATING CURRENT SYSTEMS

Plant of the Rutland Railway, Light and Power
Company

BULLETIN No. 9

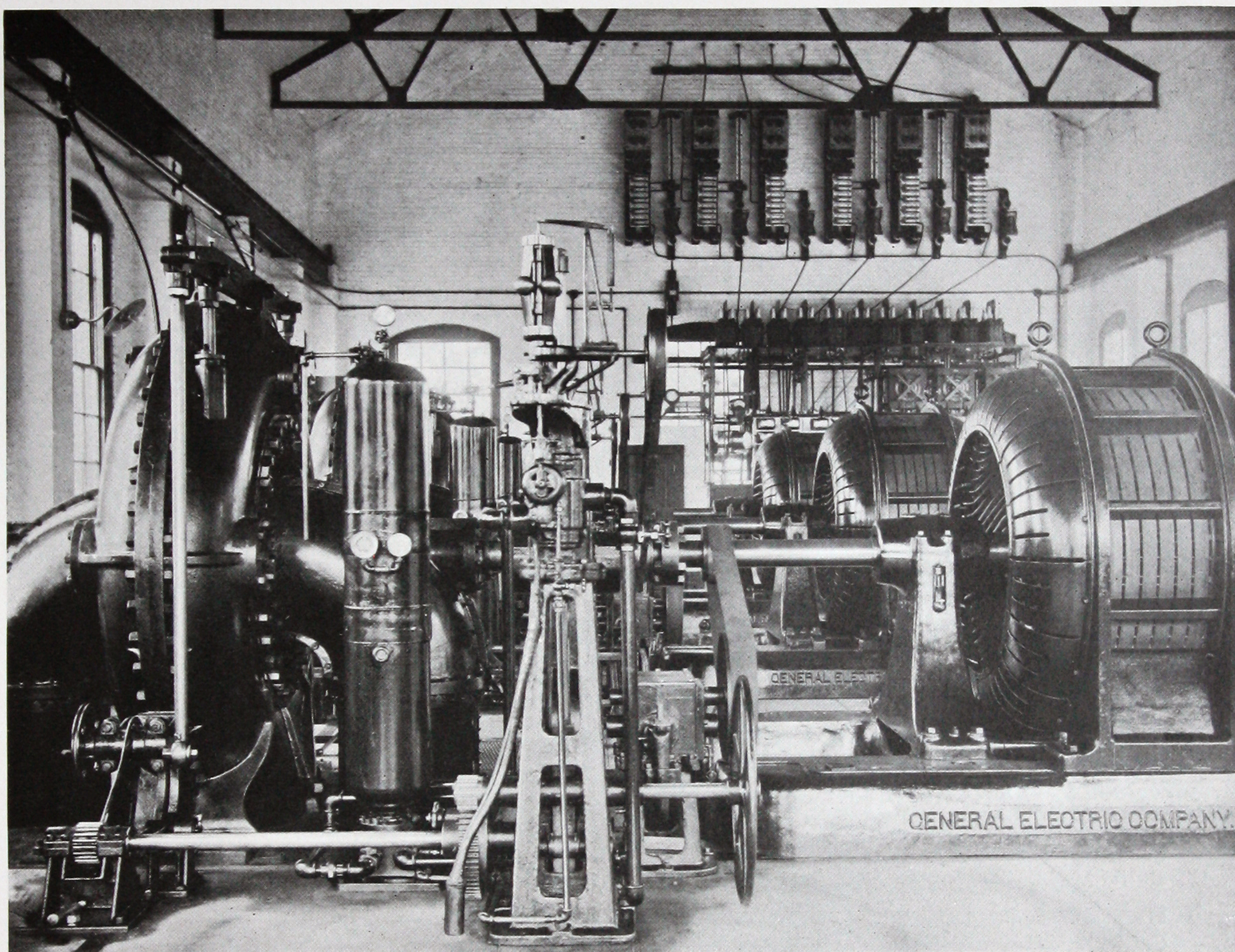
OCTOBER, 1907



MENDON POWER HOUSE, EXTERIOR

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MENDON POWER HOUSE, INTERIOR

CLOSE load regulation is of particular importance when both lighting and variable power are furnished from the same generators or over the same transmission lines. Satisfactory illumination with the improved lighting devices of recent years is largely dependent on close voltage regulation, which frequently is to be obtained only under relatively steady loading conditions. In a great number of cases separate groups of generators are run for lighting and power loads

and separate transmission lines are used; even when it is possible to run both loads on the same generators it is often necessary to employ separate transmission lines to obtain satisfactory voltage regulation at the receiving stations.

The problem of closely governing the speed of water wheels and slow speed reciprocating engines is especially difficult with sharp variations of load. If the load variations can be eliminated under these conditions, speed

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and voltage regulation becomes an easy matter and oftentimes economies are to be obtained by combining the two loads and operating units in accordance with the total average demands, or if the load is transmitted over duplicate high tension lines, only one line need be in service while the other may be held in reserve for accident or repairs.

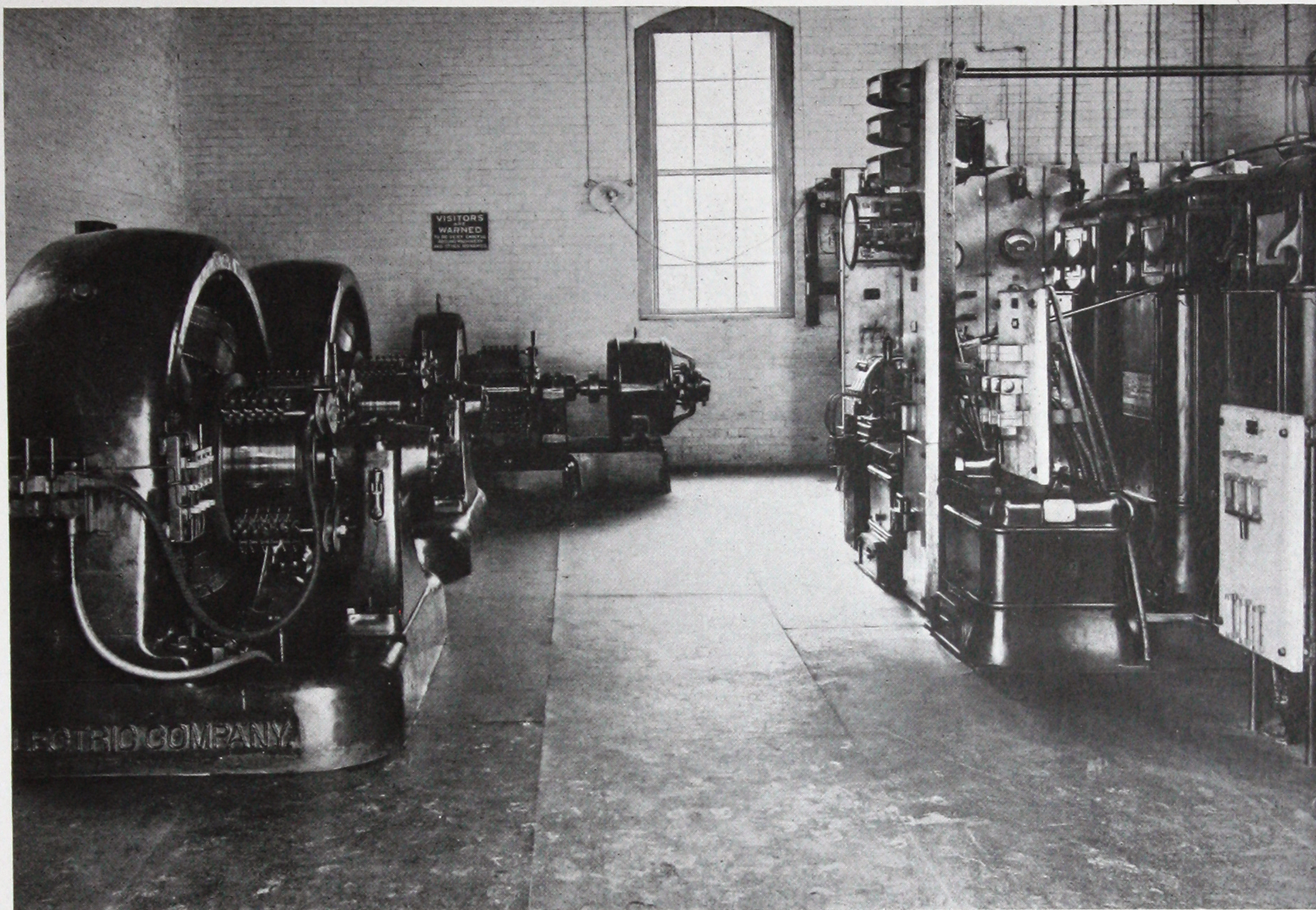
Storage batteries with automatic regulating boosters are at present the only satisfactory way of accomplishing such load regulation. The battery alternately charges and discharges the difference between the instantaneous and average demands through a "regulating booster" or reinforcing generator, whose field is so automatically controlled that it compensates for the difference between the battery and line voltages and forces the battery to charge and discharge in accordance with the load variations. The regulation may be made to depend on either alternating or direct current load variation, and the battery charge and discharge may be either into some direct current supply circuit of the system, or, if there is no such direct current circuit, converted from alternating to direct current on charge, and from direct to alternating current on discharge, by the use of a suitable motor generator set or combined rotary converter and booster.

A large number of plants are in service where the regulation is accomplished by direct current control. In this field the Gould Storage Battery Company has been most successful in

accomplishing close regulation. This is due to the early recognition by this company of the essential points entering into the successful solution of the problem. An experience covering a number of years has demonstrated the efficiency and reliability of its method of booster control.

The Gould Regulating Booster System employs a regulating coil carrying a definite shunted portion of the generator load, which coil forms the field of an auxiliary exciting machine, usually mounted on the same shaft with the booster generator and driven at virtually constant speed by a motor. The voltage of this machine is therefore proportional to the generator load. The armature leads from this machine are placed across the line, one lead including the booster field. The *difference* in voltage between the exciter machine and the line is therefore impressed on the booster field; the exciter is therefore usually termed a Counter Electro-Motive Force Generator, or more shortly a C. E. M. F. machine. With a slight decrease in the generator load, the booster field is thus excited in a direction to cause the booster to reinforce the line voltage as applied to the battery and thus cause the battery to charge; with an increase in generator load the excitation is in the opposite direction and the booster causes the battery to discharge. The controlling element in the battery and booster operation, according to the Gould method, is thus a variation of

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RUTLAND SUBSTATION, INTERIOR

the load to be regulated, and with proper field winding the regulation may be made as close as is desired.

Previous schemes employed a regulating coil in the load or "work circuit," and the battery charge and discharge depended on the condition or state of the charge of the battery. With this arrangement, close regulation could not be obtained; when attempted, the operation of the battery became unstable. The success of the Gould Storage Battery Company's booster scheme has resulted in the general practice of placing the regulating coil in the circuit carrying the current to

be regulated. Other schemes for the field regulation employ mechanical devices, with necessarily accompanying inertia, whereas the Gould method depends on electro-magnetic changes which can be made practically instantaneous. Moreover, the Gould booster is a single self-contained piece of apparatus with no mechanical complications to get out of order, a great advantage from an operating standpoint.

The application of this method to alternating current regulation is an important step and represents a great advance in the use of storage batteries.

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The Gould Storage Battery Company has installed the first and, to date, the only successful regulating storage battery where the battery duty is controlled directly by alternating current load variations. In this installation, small series transformers are employed in the load circuit to be regulated; a synchronous rotary rectifier converts the current from these transformers into direct current for the excitation of the field of the C. E. M. F. machine in such a way that this excitation is proportional to the true energy component of the alternating current load. This plant was installed for the Rutland Railway, Light and Power Company at Rutland, Vermont, and accepted during November, 1906, after a most thorough test by the consulting engineers, Messrs. French & Bryant, Boston, Mass. It has been in constant successful operation ever since.

The essential features of the power supply and substations of the Rutland Railway, Light and Power Company are described below.

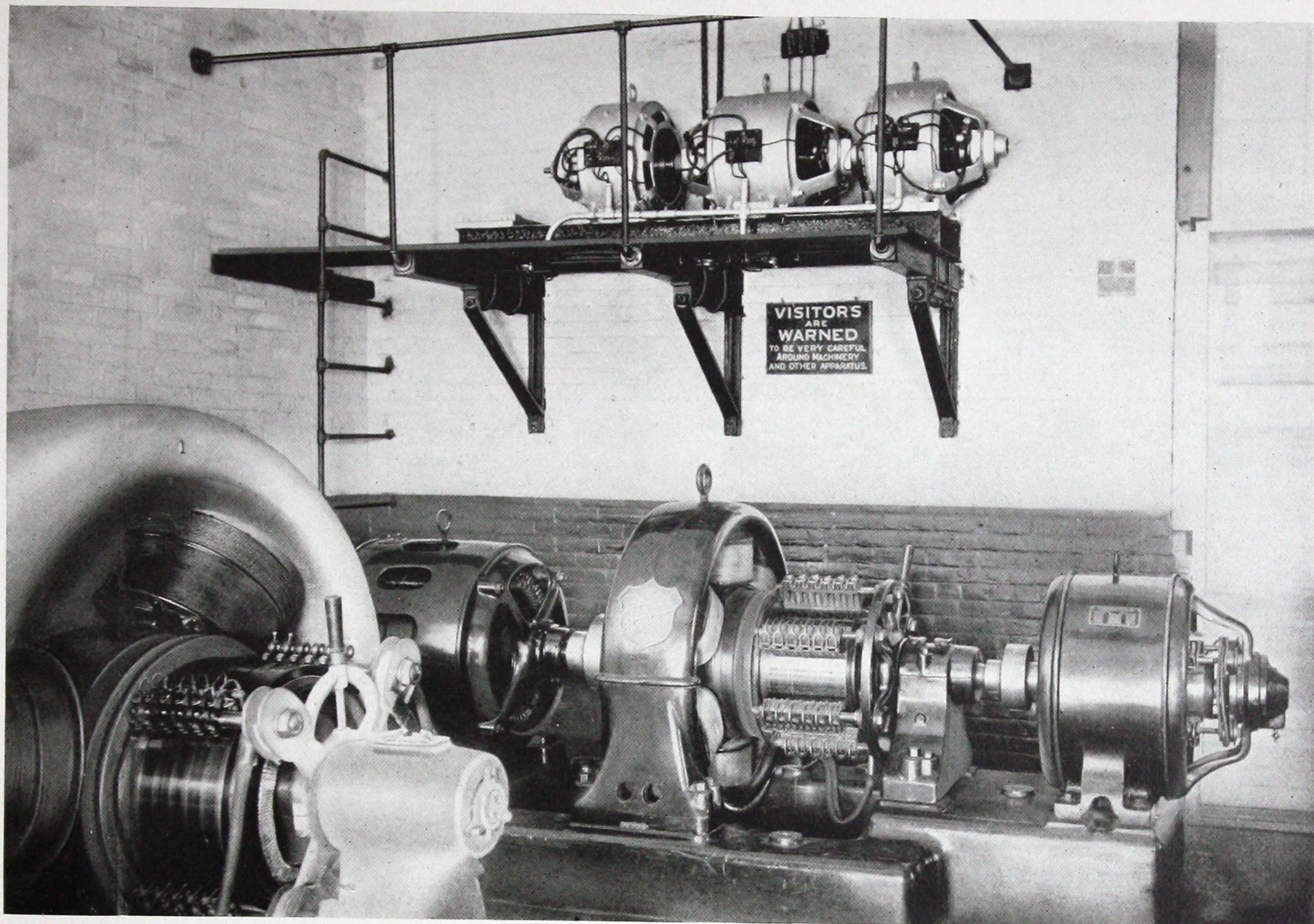
The power house is located at Mendon, about four miles distant from Rutland, and contains three 400-kilowatt, 13,200-volt, 25-cycle, 3-phase, revolving field generators, with space for a fourth machine. Each of these is direct coupled to S. Morgan Smith 90-inch horizontal double discharge turbines with Lombard governors. Two 45-kilowatt, 125-volt exciters are also direct coupled to separate turbines with governors. These turbines are

supplied with water at 200 feet head, through a 60-inch penstock 8000 feet in length, with a regulating tower and tank 220 feet high, the latter supported by a steel tower immediately outside of the power house. The function of the tower is to act as a relief valve and absorb the water hammer on sudden reduction of load and also to act as a pressure equalizer. The premium to be placed on close regulation with the extremely long penstock, from this standpoint alone, is evident at once if the energy of the water flow is considered. This installation only utilizes the drop between the lower reservoir and the power house. A second development between the upper and lower reservoirs at 475 feet head is possible for future increase.

Two 3-phase lines on separate poles connect the power house with the main distributing station at Rutland. This latter contains a 500-kilowatt frequency changer set for the lighting load and three 125-kilowatt, 13,200 to 380-volt transformers and two 150-kilowatt, 600-volt General Electric rotary converters for that part of the railway load supplied from this station.

The Castleton substation is connected with the Rutland substation by a single 3-phase line, 12.5 miles in length. At Castleton substation there are three 150-kilowatt transformers, 13,000 to 380 volts, and two rotary converters of 150 and 200 kilowatt capacity. This substation

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REGULATING BOOSTER SET

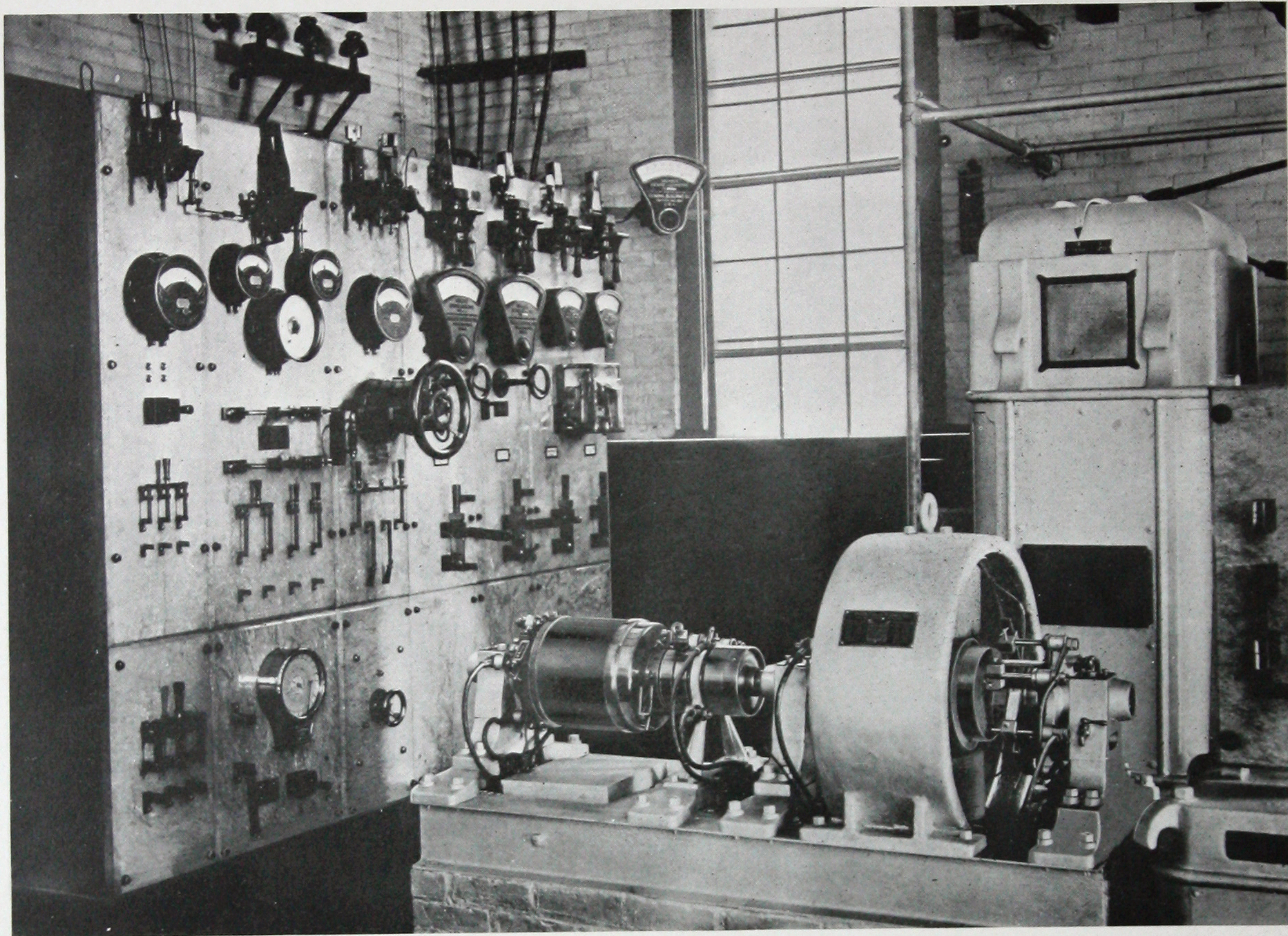
supplies the railway load for the western end of the railway between Rutland and Fair Haven and a branch line to Bomoseen Park.

At Rutland the Gould Storage Battery Company installed 280 cells, having a capacity of 400 amperes for one hour or 800 amperes for twenty minutes, in a building adjacent to the substation. In the substation itself is installed the regulating apparatus, comprising series transformers, a synchronous rotary rectifier and the booster set proper. In this installation it was necessary to furnish an additional machine set to obtain constant voltage

as the rotary converters are compound wound and on inversion there is a considerable drop in voltage.

The series transformers are in the incoming line and regulate the load on both the Rutland and Castleton substations. It will be seen then, that at times of heavy load on both substations the battery must discharge into the Rutland load directly; when the load is light at Rutland and heavy at Castleton, the Rutland rotaries must invert a portion of the battery discharge, and when light at both places the battery must charge. A simplified diagram illustrates the functions of the apparatus.

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ROTARY RECTIFIER AND SWITCHBOARD PANELS

The following quotation from the report of Messrs. French & Bryant, engineers, on the acceptance tests gives the regulation obtained from this plant:

"The contract made with the Gould Storage Battery Company requires that the battery shall have a discharge capacity of 400 amperes for one hour or 800 amperes for twenty minutes; also that the variations of the alternating current (load) on the power station feeder lines, caused by varying loads on the rotaries, shall not exceed 5 per cent. plus or minus.

"It was to determine the degree of conformity with these requirements that the tests were made.

"The first series was made between midnight and 5 A.M. of the morning of November 3d, 1906, while there was no commercial load on the system taking power from Mendon station.

"The general purpose was to apply constant loads of 300 amperes at 550 volts or thereabouts at both the Rutland and Castleton substations, applying quickly at Castleton another 500 to bring the total to 1100 amperes. These

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conditions conform to those discussed when proposals were received and the apparatus was designed, and they were closely followed in the tests.

"The loads applied were water resistances, and the speed of application was therefore that of dropping the terminals into the water barrels.

"These first tests were terminated before they were repeated as frequently as was desired because of the necessity of moving cars on the railway. Additional tests were therefore made after luncheon by utilizing the ordinary rail-

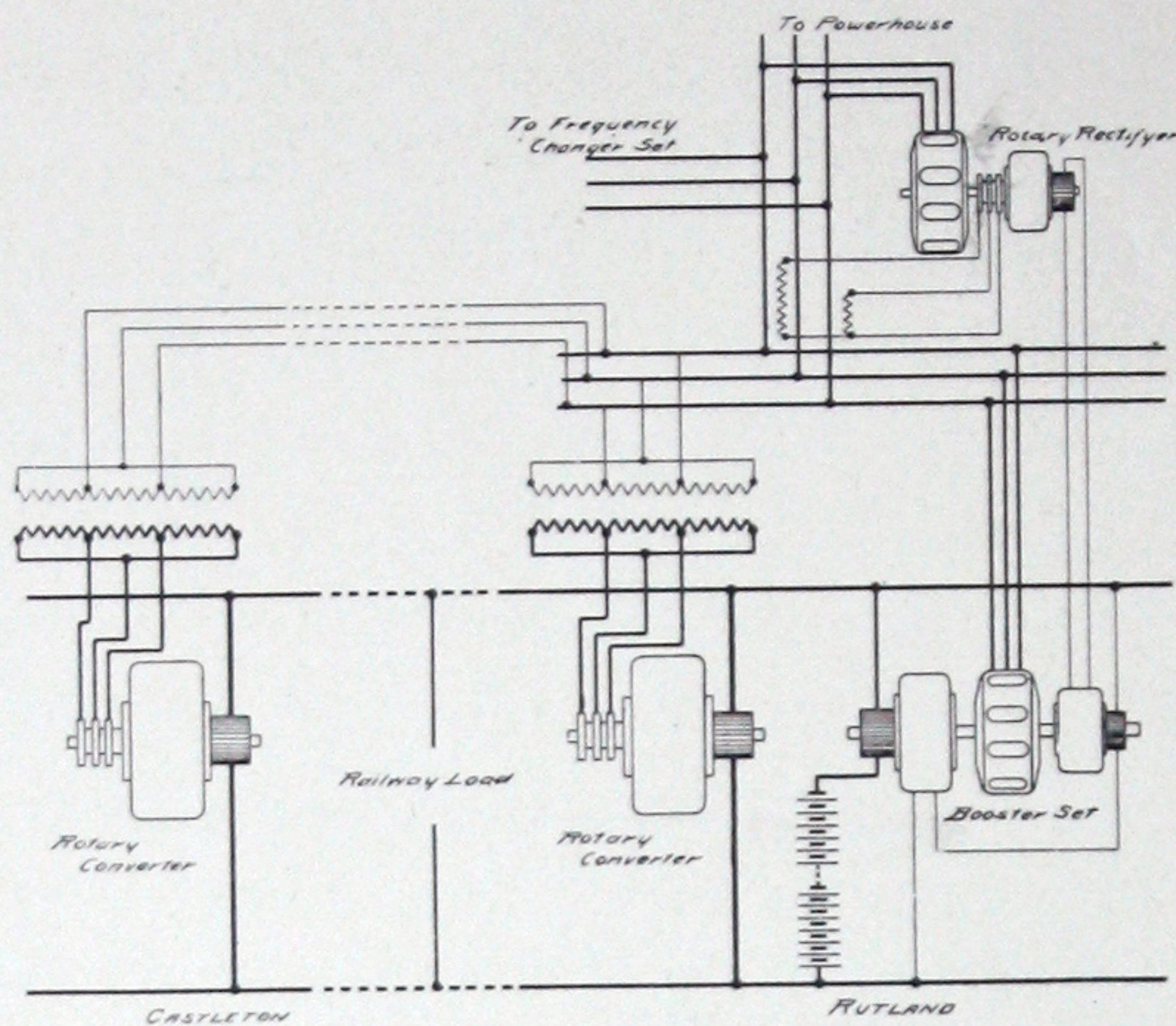
way load augmented by water barrels at Castleton and two heavy four-motor closed cars stationed near Castleton which were operated irregularly and roughly with brakes applied. These last tests produced variations from the contemplated mean loading, which were much more severe than the plant was designed to carry and decidedly more than should be expected in actual operation.

"The figures for regulation above or below the mean are as follows: Duration of each complete test, five minutes.

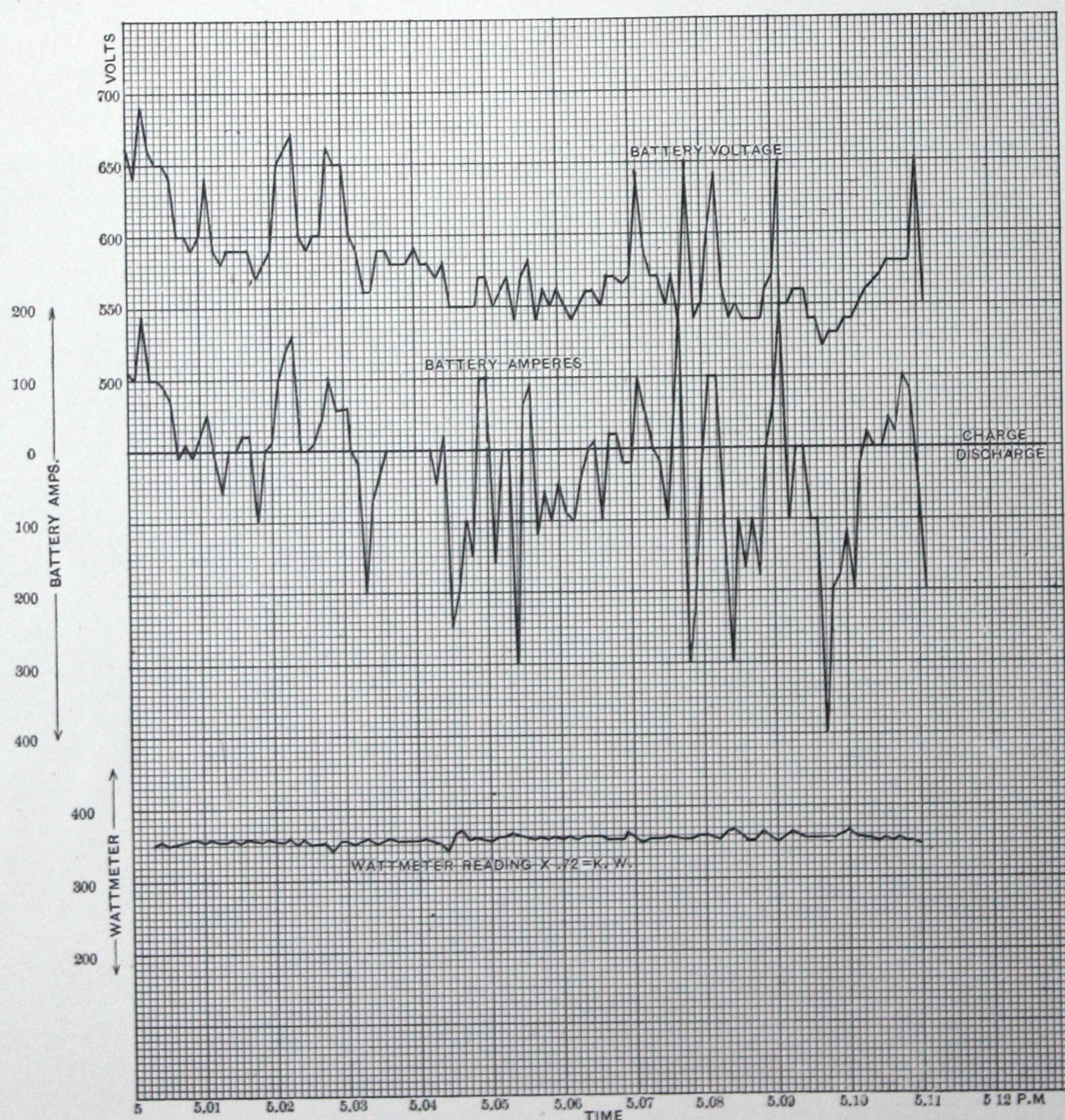


BATTERY ROOM

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SIMPLIFIED DIAGRAM OF CONNECTIONS



LOAD REGULATION. PLANT OF RUTLAND RAILWAY, LIGHT AND POWER CO., RUTLAND, VT.
 CURVE SHOWING REGULATION OBTAINED

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SERIES NO. 1

		Regulation
Test No. 1	$2\frac{6}{10}$	per cent.
Test No. 2	3	" "
Test No. 3	$5\frac{7}{10}$	" "

SERIES NO. 2

Test No. 1	6	" "
Test No. 2	$3\frac{1}{4}$	" "
Test No. 3	$3\frac{2}{10}$	" "
Test No. 4	13	" "
Test No. 5	3	" "
Test No. 6	$4\frac{7}{10}$	" "
Test No. 7	11	" "
Test No. 8	26	" "

"It is our judgment that the regulating apparatus when worked within the required and normal limits, gives you effective regulation either way within five per cent.

"Mr. Haley proposes to operate the railway for a time with the battery in use. This will give a better indication of what the real value of the regulation is to the power station than will the tests on which we have reported. We are certain that it will be found that the regulation is very close indeed, much closer than shown by the tests.

"We recommend that the battery equipment be accepted."

It is to be noted that the tests, Series No. 2, as mentioned in Messrs. French and Bryant's report, show conditions much more severe than originally contemplated and involve loads upon the apparatus beyond those for

which it was designed or is likely to meet in practice. Within the capacity of the apparatus the regulation is well within the guaranteed five per cent.

Among the advantages of the close regulation obtained may be mentioned the following:

Virtually constant speed and frequency regulation of the generators.

Constant generator station voltage.

Elimination of shock in the penstock.

Constant receiving station voltage and frequency, and therefore excellent voltage regulation on lighting circuits.

By removal of peak loads, a virtual increase of generating capacity.

This installation opens up a new field for the use of storage batteries, and as a result of its success, contracts for similar installations have been placed with the Gould Storage Battery Company.

The Gould Storage Battery Company undertakes the installation of complete storage battery plants and will gladly furnish estimates and specifications on request. The services of its Engineering Department are at the disposal of prospective purchasers and it will be pleased to advise as to the applicability of storage batteries for any particular service.

Gould Storage Battery Co.



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WORKS: Depew, N. Y.

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